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Evaluation of the suitability of weekly peak expiratory flow rate measurements in monitoring annual decline in lung function among patients with asthma and chronic bronchitis

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SUMMARY

Background. Early detection and treatment of patients with asthma or chronic bronchitis who have a rapid annual decline in lung function is essential in order to improve their long-term prognosis. This annual rate of decline can be assessed accurately by monitoring the forced expiratory volume in one second (FEV₁) which is a routine procedure in hospital respiratory laboratories but not in general practice. General practitioners usually measure patients' peak expiratory flow rate (peak flow) to evaluate lung function. If annual decline in lung function can be assessed by monitoring peak flow, this method could be used in general practice for detecting patients at an early stage who have a rapid decline.

Aim. A study aimed to investigate the long-term correlation between FEV₁ and peak flow among a group of patients in Nijmegen, the Netherlands.

Method. FEV₁ and peak flow were monitored in 53 patients with moderate asthma and 78 patients with moderate chronic bronchitis over four years. FEV₁ was measured in a laboratory once every six months and peak flow was measured by patients once a week. The correlation between the two sets of measurements was studied for each patient.

Results. Four-year data for 83 of the 131 patients were analysed; the other 48 patients received inhaled steroids during the second half of the study period so their data were not considered for all the analyses. Of the 83 patients, 35 (42%) showed a decrease in both FEV₁ and peak flow. Thirty six patients (43%) showed a decrease in FEV₁ and an increase in peak flow. Four patients (5%) showed an increase in FEV₁ and a decrease in peak flow and eight patients (10%) showed an increase in both rates. Approximately similar results were seen in a separate analysis of all 131 patients during the first two years of the study.

Conclusion. No long-term correlation was found between FEV₁ and peak flow. Peak flow is not capable of detecting annual decline in lung function. Therefore it cannot be used to detect patients with asthma or chronic bronchitis who have a rapid annual decline in lung function. Spirometers,

which measure peak flow and FEV₁, could be used in general practice. These would allow general practitioners to continue measuring peak flow in order to assess short-term changes in lung function while providing an important means for monitoring FEV₁ to assess long-term changes in lung function.

Keywords: asthma; airways obstruction; peak expiratory flow recordings; lung function.

Introduction

THERE is an increased appreciation of the importance of using objective parameters such as peak expiratory flow rate (peak flow) in the diagnosis and treatment of patients with asthma and chronic bronchitis (chronic obstructive pulmonary disease).^{1,2} The peak flow represents the maximum flow of air attained during a forced expiratory manoeuvre and corresponds to the peak on a flow-volume curve. This maximum flow during expiration is reduced in patients with airway obstruction, for example those with asthma or chronic bronchitis. The rate has been shown to be a simple and reproducible parameter in assessing airway obstruction.³ The peak flow meter is a cheap and simple device that is commonly used in general practice and by asthmatic patients in self-management programmes. A patient's measured peak flow value can be compared with a predicted value (obtained from standard reference charts) or with the patient's personal best (measured during a symptom-free period) to determine the presence or absence of airway obstruction. Other common uses of peak flow measurements are in the assessment of diurnal variability, day-to-day variability and reversibility of airway obstruction.⁴ The greater the variability the more prone are the airways to bronchial constriction.

The forced expiratory volume in one second (FEV₁) is another objective parameter which has been established as the best measure for assessing severity of airway obstruction.³ Owing to the complexity and high costs of the necessary apparatus it has until recently only been used in hospital respiratory laboratories. Since the introduction of portable, easy-to-use, low-cost spirometers, patients' FEV₁ is occasionally being measured in general practice. FEV₁ has been shown to be an important index for assessing severity of airway obstruction and for estimating its progression and is so far the only parameter that has been shown to predict asthma mortality.⁵ In adults, FEV₁ shows a physiological decline with age.^{6,7} This annual rate of decline is greater in asthma and chronic bronchitis sufferers compared with non-sufferers.⁸ It is possible to detect patients with a high annual rate of decline in lung function by means of serial FEV₁ measurements. Early detection followed by adequate treatment of such patients has been shown to reduce this rate of decline, thereby improving patients' long-term prognosis.⁹

FEV₁ and peak flow measurements show a close correlation in cross-sectional studies.¹⁰ Although many longitudinal studies have investigated the course of FEV₁ over time, little is known

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about the course of peak flow over time and its long-term correlation with FEV₁. If peak flow is shown to have a close long-term correlation with FEV₁, it could be used in general practice to detect patients with a fast, progressive form of asthma or chronic bronchitis. A study was carried out to investigate the long-term correlation between FEV₁ and peak flow.

Method

Patient selection and participation

The study was approved by the medical ethics committee of the University of Nijmegen, the Netherlands. Twenty nine general practitioners in the catchment area of the university selected patients for the four-year study. A total of 223 patients aged 30 years or over with moderate airway obstruction owing to asthma or chronic bronchitis were selected for the study.¹¹ Of the patients selected, 131 (53 with asthma and 78 with chronic bronchitis) completed the four-year follow up during which FEV₁ and peak flow measurements were made.

The only medication allowed during the first two years of the study were the bronchodilators salbutamol or ipratropium bromide. At the end of the second year the annual rate of decline in FEV₁ was calculated for each patient by means of regression analysis. Patients were then divided into two groups according to the magnitude of their annual rate of decline. The first group comprised 48 patients with an annual rate of decline in FEV₁ greater than 0.08 l year⁻¹ (26 of whom had asthma). The second group comprised the 83 patients whose rate of decline in FEV₁ was less than 0.08 l year⁻¹ (27 of whom had asthma). Beclomethasone dipropionate inhalations 400 µg twice daily were added to the medication of all patients in the first group. No additional medication was given to patients in the second group. Both groups were monitored for a further two years.

FEV₁

FEV₁ measurements were performed once every six months at the Department of Pulmonology, Dekkerswald, the Netherlands by two trained laboratory assistants. FEV₁ was measured using an integrating flow meter (Microspiro HI-298®, Chest Corporation).¹² Patients were instructed to refrain from bronchodilator therapy for at least eight hours before measurement. At each measurement three forced expiratory manoeuvres were carried out. The difference between the highest and the lowest FEV₁ values had to be less than 0.1 l; if this was not the case, patients were asked to try again after a few minutes' rest. The FEV₁ of the attempt with the highest sum of FEV₁ and forced vital capacity was retained for statistical analysis. All measurements were made during periods free from exacerbations. Exacerbations were defined according to Fletcher, modified according to Boman and colleagues.¹³ In total nine half-yearly FEV₁ measurements per patient were available for analysis.

Peak flow

Peak flow was measured using an Assess® peak flow meter (Health Scan Products).¹⁴ All patients were given a peak flow meter and were taught to measure their own rate. Patients were asked to measure their peak flow once a week on the same day, three times in the morning, and to record all results in a diary card. All measurements were made before using bronchodilator medication. The patient's technique in measuring and recording peak flow was checked at each visit to the lung function laboratory. The highest of the three peak flow measurements was considered for analysis. In total, 208 weekly peak flow measurements per patient were available for analysis.

Patient symptoms and smoking history

Patients recorded their symptoms on the Dutch version of a Medical Research Council respiratory symptoms questionnaire. The numbers of symptoms recorded were added together and presented as a score ranging from zero to eight. Smoking history was assessed in pack years, a pack year being defined as 25 cigarettes per day per year.

Longitudinal correlation between FEV₁ and peak flow

Data for all 131 patients were analysed for the first two years of the study. Five FEV₁ and 104 peak flow measurements per patient were considered for regression analysis. There were no missing values during the first two years. The regression coefficient of the FEV₁ and of the peak flow were calculated and the former was then plotted against the latter for each patient.

Data for the 83 patients in the group not receiving inhaled corticosteroids were analysed for the four years of the study. Nine FEV₁ and 208 peak flow measurements per patient were considered for regression analysis. There was one missing FEV₁ value in the third year and three in the fourth year, thus, four patients had eight instead of nine FEV₁ measurements. In these cases the regression coefficient was calculated for the available measurements. For each of the 83 patients, the regression coefficient of the FEV₁ was calculated and plotted against the regression coefficient of the peak flow.

Cross-sectional correlation between FEV₁ and peak flow

FEV₁ was measured on nine occasions. Nine corresponding peak flow values were obtained by calculating the mean of five consecutive weekly peak flow values for each FEV₁ value (the third peak flow value corresponded with the week of FEV₁ measurement). The mean FEV₁ and mean peak flow values for patients in the first group (that is, patients who received inhaled corticosteroids during the third and fourth years of the study) and patients in the second group (those who did not receive inhaled corticosteroids) were then plotted on a time scale.

Patient characteristics associated with a high correlation between FEV₁ and peak flow

A correlation coefficient of 0.6 or greater between the slopes of a patient's FEV₁ and peak flow was defined as being a high correlation and a correlation coefficient of less than 0.6 was defined as being low. Various patient characteristics, for example age, symptom score, number of pack years of cigarettes, bronchial hyper-responsiveness and percentage airway reversibility, were analysed to determine whether any patient characteristics were associated with a high correlation between FEV₁ and peak flow.

Statistical tests

The difference in the distribution of nominal variables between patients who had a high or low correlation coefficient between their FEV₁ and peak flow was tested using the chi square test. Continuous variables were tested using the unpaired *t*-test. The Wilcoxon test was used to test the difference in patients' bronchial hyper-responsiveness.

Results

Longitudinal correlation between FEV₁ and peak flow

Two-year follow up. The relationship between the regression coefficients of the FEV₁ and of the peak flow for each of the 131 patients during the first two years of the study is shown in Figure 1. In total 88 patients (67.2%), of whom 36 had asthma, showed a decrease in FEV₁ and 59 patients (45.0%), of whom 19 had

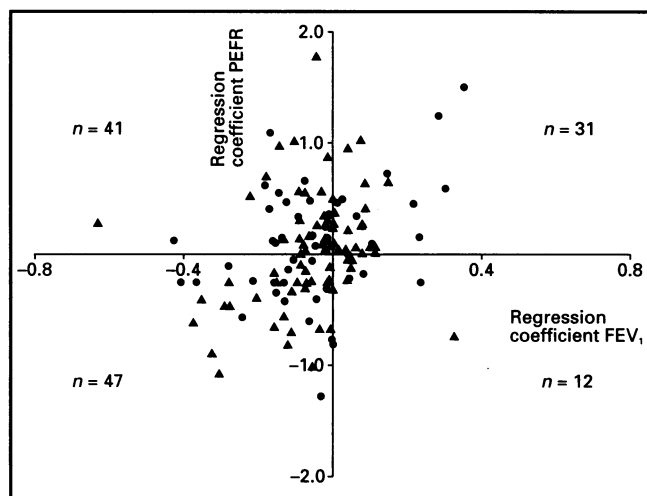


Figure 1. Relationship between the regression coefficients of FEV₁ and peak expiratory flow rate (PEFR) for each of the 131 patients during the first two years of the study, where ● = patients with asthma and ▲ = patients with chronic bronchitis (n = number of patients).

asthma, showed a decrease peak flow during this period. Forty seven patients (35.9%), 16 of whom had asthma, showed a decrease in both FEV₁ and peak flow. Forty one patients (31.3%), 20 of whom had asthma, showed a decrease in FEV₁ and an increase in peak flow. Twelve patients (9.2%), three of whom had asthma, showed an increase in FEV₁ and a decrease in peak flow. Thirty one patients (23.7%), 14 of whom had asthma, showed an increase in both rates.

Four-year follow up. The relationship between the regression coefficients of the FEV₁ and of the peak flow for each of the 83 patients not receiving inhaled corticosteroids followed up over four years is shown in Figure 2. In total 71 patients (85.5%), 17 of whom had asthma, showed a decrease in FEV₁ and 39 patients (47.0%), of whom 13 had asthma, showed a decrease in peak flow during this period. Thirty five patients (42.2%), 10 of whom had asthma, showed a decrease in both FEV₁ and peak flow. Thirty six patients (43.4%), seven of whom had asthma, showed a decrease in FEV₁ and an increase in peak flow. Four patients (4.8%), three of whom had asthma, showed an increase in FEV₁

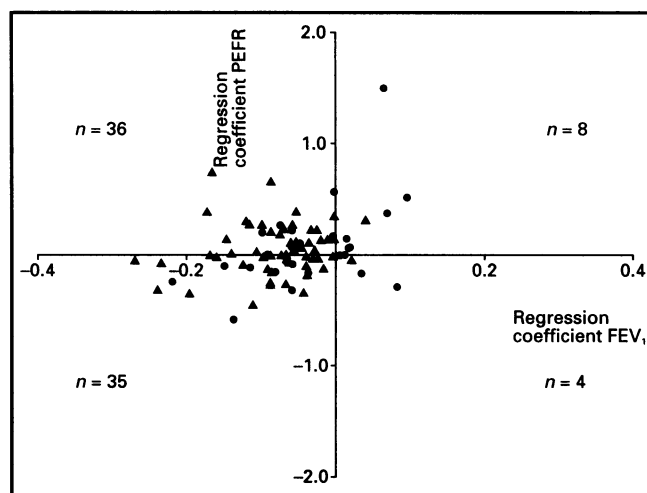


Figure 2. Relationship between the regression coefficients of FEV₁ and peak expiratory flow rate (PEFR) for each of the 83 patients during the four-year period, where ● = patients with asthma and ▲ = patients with chronic bronchitis (n = number of patients).

and a decrease in peak flow. Eight patients (9.6%), seven of whom had asthma, showed an increase in both rates.

Cross-sectional correlation between FEV₁ and peak flow

The mean FEV₁ and peak flow values for the 48 patients in the first group and the 83 patients in the second group over the four years are shown in Figure 3. Patients in the first group showed a decline in FEV₁ of 0.16 l year⁻¹ during the first two years of the study while peak flow remained stable. Patients' FEV₁ and peak flow increased during the initial six months of treatment with inhaled corticosteroids (FEV₁ increased by 0.46 l year⁻¹). Although FEV₁ decreased after this initial treatment effect (by 0.10 l year⁻¹) peak flow remained stable. The decline in FEV₁ during this period was 0.06 l year⁻¹ less than the rate of decline before treatment with inhaled corticosteroids. FEV₁ of patients in the second group showed a progressive decline over the four years of the study while peak flow remained approximately the same.

Patient characteristics associated with a high correlation between FEV₁ and peak flow

A total of 101 patients had a correlation coefficient of less than 0.6 between their FEV₁ and peak flow (low correlation group) and 30 patients had a correlation coefficient of 0.6 or greater (high correlation group). No patient characteristics were found to be associated with a high correlation between FEV₁ and peak flow (Table 1). Patient characteristics that were asthma-related such as bronchial hyper-responsiveness, reversibility of airway obstruction, atopy and a diagnosis of asthma, were associated with a high correlation between FEV₁ and peak flow, but none of the characteristics showed a significant difference between the two groups.

Discussion

The present study failed to demonstrate a long-term correlation between FEV₁ and peak flow in patients with moderate asthma or chronic bronchitis. The majority of patients showed a long-term decline in FEV₁ while only a few showed a decline in peak flow. The percentage of patients showing a decline in FEV₁ increased over time. There was, however, only a marginal increase in the percentage of patients showing a decline in peak flow. The short-term effect of inhaled corticosteroid treatment on the level of FEV₁ and peak flow during the first half of the third year showed a possible correlation on a group basis. Although asthma patients showed a high correlation between peak flow and FEV₁, no patient characteristics were found that could predict a high correlation between the two rates. Hence it can be concluded that, unlike the FEV₁, peak flow is not capable of detecting the annual

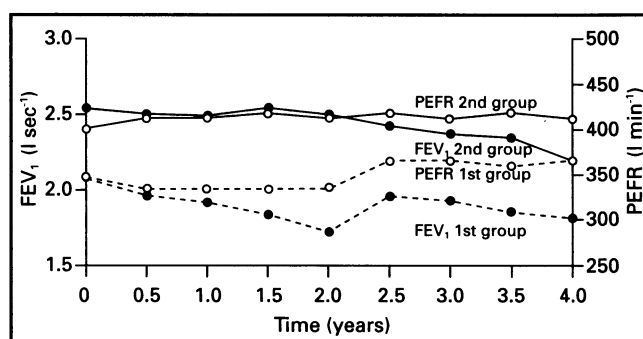


Figure 3. Mean FEV₁ and peak expiratory flow rate (PEFR) values for 48 patients in the first group (those taking inhaled corticosteroids in the third and fourth years of the study) and 83 patients in the second group (those not taking inhaled corticosteroids) over the four years of the study.

Table 1. Patient characteristics associated with a high or low correlation between FEV₁ and peak expiratory flow rate (PEFR).

Patient characteristics	Characteristics of group in which correlation between FEV ₁ and PEFR	
	Low ($r < 0.6$)	High ($r \geq 0.6$)
No. of patients	101	30
Age (years)	52	50
Sex (no. of men)	59	13
Symptom score	5	5
No. of pack years of cigarettes	17	15
Smoker (% of group)	56	40
FEV ₁ (l sec ⁻¹)	2.4	2.2
FEV ₁ (% of predicted value)	76	73
Bronchial hyper-responsiveness (PC ₂₀)(mg ml ⁻¹)	4	2
PEFR (l min ⁻¹)	553	525
Reversibility of airway obstruction (%)	16	22
Atopy (% of group)	24	33
Asthma (% of group)	36	57

decline in lung function in adults with moderate asthma or chronic bronchitis.

The general practice management of asthma, including self-management, is based on daily peak flow measurements, whereby the 'traffic light' system of colour-coded peak flow measurement zones provides the patient with an easy to understand method of maintaining lung function at the highest possible level.¹ The effect of appropriate medical intervention can also be demonstrated by short-term monitoring of peak flow: the present study showed a rise in peak flow during intervention with inhaled corticosteroids. Peak flow has also been shown to be a reliable measure of the reversibility of airways obstruction.⁴ Other investigations have shown a good short-term relationship between peak flow and FEV₁.¹⁰ Peak flow can, therefore, be considered as a reliable parameter for monitoring short-term changes in lung function in patients with asthma or chronic bronchitis.

FEV₁ provides an integrated index of the maximum flow during $\pm 75\%$ of the expiratory flow-volume curve.¹⁵ Peak flow mainly reflects the conductance in the central airways and is responsible for only the initial part of the flow-volume curve. Both FEV₁ and peak flow are known to be effort-dependent and relatively insensitive to minor changes in the calibre of peripheral airways. The time span within which the two parameters are measured is therefore a possible explanation for the difference in sensitivity to minor changes in maximum flow of air.

No long-term correlation was found to exist between peak flow and FEV₁. The consequence of this fact is of clinical importance. A patient with a stable peak flow, measured during consecutive consultations, can have a rapid decline in FEV₁ which can proceed unnoticed if the FEV₁ is not assessed. Peak flow is therefore not suitable for detecting patients at an early stage who have a rapid decline in lung function. Since early detection and treatment of patients with asthma or chronic bronchitis is the only way to improve the long-term prognosis of these patients, general practitioners could consider using a spirometer for monitoring lung function in adults. Modern portable spirometers are inexpensive and easy to use. In the near future much cheaper and more accurate spirometers are expected. Almost all portable spirometers also measure peak flow. Such an instrument would allow general practitioners to continue measuring peak flow in order to assess short-term changes in lung function while providing an important means for monitoring FEV₁ for the assessment of long-term changes in lung function.

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